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Final Report

to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

for

SUPPORT OF SELECTED X-RAY STUDIES TO BE PERFORMED USING DATA FROM THE UHURU (SAS-A) SATELLITE

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I. INTRODUCTION

A study of the diffuse X-ray background using Uhuru satellite data was initiated at Caltech for the purpose of obtaining specific information on:

1) The distribution of X-rays originating from selected regions of the galaxy in at least two energy bands.
2) The mean spectrum of the disc component for several longitude ranges.
3) The angular fluctuations in the X-ray background down to 1% in $5^{o} \times 5^{o}$ cells over a substantial portion of the celestial sphere in two energy bands.
4) The energy spectrum of the cosmic X-ray background in the 2-18 keV band, especially to seek evidence for a change in spectral slope above 10 keV.
5) Variations in the non-cosmic X-ray background as a function of geographic position, solar and magnetic activity and solar illumination.

The above objectives were broader in scope than could be accomplished within the limited budget of the program; however, the objectives remain important to our future studies from the HEAO-A spacecraft and our current rocket-borne observations at lower energies. As will be discussed below, these objectives had to be considerably descoped, both from alleged conflicts with ongoing AS&E programs and difficulties in obtaining appropriate data from AS&E. Following a meeting with Drs. R. Giacconi,

H. Gursky and T. Matilsky, a letter of understanding was written to Dr. Giacconi to limit the scope of the investigation to areas related to the soft X-ray program and specific topics of mutual interest that could be worked on in collaboration with the AS&E scientists.

From existing published data it was essentially impossible to evaluate the amount of data required to provide a 1% statistical accuracy on diffuse background data. Much depended on the fraction of each tape containing useable data. A conservative estimate requested 96 tapes. As analysis of Caltech rocket observations progressed on the Gemini-Monoceros enhancement and the Vela region, an additional 19 tapes were requested to cover these portions of the sky.

After reducing three of the best tapes, it was clear that even more data would be required to reach the level of statistical precision deemed necessary to extract the small galactic contribution to the diffuse flux above 2 keV. Only 24% of an average day's data was nighttime data for which an equation of motion could be determined. Only 25% of this data was useful sky data, since much of the sky data was contaminated by particles or telemetry dropouts and noise. In order to do any kind of complete sky study, nearly 200 days of data with scans going to high galactic latitude would be required.

In actual fact, only 13 tapes were sent to us by AS&E. Of these, one was empty, two scanned along the galactic plane, two had so little data as to make superposition impossible, and two scanned very close to the plane ($|b| < 20^{o}$), but not over the regions we requested. This left us with six useful tapes, three of which had nearly overlapping scan

paths while two others overlapped on a different scan path. The total amount of useful nighttime data reduced to 1.1 days, of which only 0.27 day was useful sky data.

The following report discusses the handling of the data and the results of the analysis. A modified version is being submitted for publication to the Astrophysical Journal. Preliminary results were presented at the AAS meeting in San Diego in August 1975.

Objectives 1 and 2 concerning emission from the galactic plane were attempted, but unsuccessful mainly because of insufficient data to achieve the required statistical precision. Objective 3 was accomplished, but only over a limited portion of the celestial sphere, again resulting from lack of good data. The fourth objective necessitated use of data exceeding 10 keV. In theory there should be two sources of this data, the $1/2^{\circ} \times 5^{\circ}$ detector which covers the range 1-20 keV and the "side-switching" capability of the detectors, which meant that at certain times the $5^{\circ} \times 5^{\circ}$ detector could detect radiation above its usual discrimination setting of 10 keV. The $1/2^{\circ} \times 5^{\circ}$ detector could not be used for this objective because of the poor statistics due to the limited field of view; the side-switching capability was not employed during the days of data at our disposal. The fifth objective was met for the Uhuru data as a byproduct of the selection of good data needed to fulfill the diffuse background objectives. Comparison with Caltech rocket flight data has proven impossible so far, since we have been unable to obtain sufficient data which overlap our objects of interest.

A positive aspect of this guest investigator program was the frequent and beneficial contact we enjoyed by letter and telephone with the AS&E staff. In particular, Drs. S. Murray, T. Matilsky, D. Koch and M. Ulmer were most helpful in answering our numerous queries with respect to data format and handling.

For future programs of a guest investigator nature, we would suggest that the guest investigator have a more deliberate hand in the selection of the data. For example, the scanpaths and total amount of good night-time data for which an aspect solution can be derived should be made public. In this way the investigator might choose, with regard to celestial position, geomagnetic field indices, and total exposure time, the data most closely satisfying his objectives. We can also see no purpose in restricting the amount of data available for analysis. This amount should be decided on the basis of the experimental objectives and the computing budget restrictions.

THE ISOTROPY AND ENERGY DISTRIBUTION OF THE DIFFUSE X-RAY SKY

by

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ABSTRACT

A new measurement of the diffuse X-ray emission sets more stringent upper limits on the fluctuations of the background and on the number counts of X-ray sources with $|b| > 20^{\circ}$ than previous measurements. A random sample of background data from the *Uhuru* satellite gives a relative fluctuation in excess of statistics of 2.0% between 2.4 and 6.9 keV. The hypothesis that the relative fluctuation exceeds 2.9% can be rejected at the 90% confidence level. No discernable energy dependence is evident in the fluctuations in the pulse height data, when separated into three energy channels of nearly equal width from 1.8 to 10.0 keV. The probability distribution of fluctuations was convolved with the photon noise and cosmic ray background deviation (obtained from the earth-viewing data) to yield the differential source count distribution for high latitude sources:

$$N(S)\ dS \simeq 8 \begin{pmatrix} +15 \\ -\ 8 \end{pmatrix} S^{-2.5}\ dS$$

at a 90% confidence level, where the slope assumes a Euclidean world model. This implies that a maximum of 160 sources are between 1.7 and 5.1×10^{-11} ergs cm^{-2} sec^{-1} (1-3 *Uhuru* counts). An analysis of the pulse height data gives a χ^2 best-fit spectrum: $dN/dE \simeq 7\ E^{-1.41 \pm .04}$ photons (cm^2-s-keV-sterad)$^{-1}$ for the diffuse X-ray background.

I. THE EXPERIMENT

The following analysis utilizes the nighttime Uhuru data for January 2-5, 1971, that is, within the first month of the satellite's operation. The scan paths for each day were approximately perpendicular to the galactic plane. (A "day" corresponds to one orientation of the spin axis.) The range in ℓ at the plane crossings was $65^{\circ} < \ell < 94^{\circ}$ and $245^{\circ} < \ell < 270^{\circ}$. A description of the vital features of the spacecraft is given by Giacconi et al. (1971). For convenience, relevant features of the instrumentation are repeated here.

The apogee of the space vehicle was about 560 km and its perigee 520 km during the observing period. The satellite spin period was 12 minutes during which time the sky and Earth alternately filled the field of view of the detectors. Two back-to-back proportional counters were oriented perpendicular to the spacecraft spin axis. One detector with $0\overset{\circ}{.}52 \times 5\overset{\circ}{.}2$ collimation (full width half maximum) gave good angular resolution, while the other detector, with a larger solid angle of $5\overset{\circ}{.}2 \times 5\overset{\circ}{.}2$, had higher sensitivity and was therefore more useful for a background study. The latter had an effective area of about 840 cm^2; it will be the detector referred to in the following discussion. The energy range of the counters was constrained at the low end by the thin beryllium windows and at the upper end by the filling gas. This range was 2.4 - 6.9 keV for the broadband data and 1.8 - 10.0 keV for the seven pulse height channels.

For this analysis only nighttime data were used to avoid contamination of the data by the sun. Pulse shape discrimination and anticoincidence

logic were employed to minimize charged particle and high energy photon contributions to the X-ray background.

II. TREATMENT OF DATA

If the techniques for rejecting solar, charged particle and cosmic ray events were 100% effective the measurement of the fluctuations would have been routine. It was the identification of such contributing factors to the fluctuations, the quantitative evaluation of their degree of influence, and subsequent determination of criteria for rejection of data which comprised the effort of the data reduction. The aim was to eliminate known and systematic sources of contamination, while leaving in the data those "glitches" which may be just the fluctuations we are trying to measure.

The following kinds of data were eliminated from the analysis: those afflicted with parity errors, instrumental noise, no pulse-shape discrimination, calibrations, lack of an aspect solution, or earth blocking. Also rejected were data which fit certain rejection criteria (described later) for charged particle, discrete source, galactic plane, or sun contamination. We list in Table 1 the percentage reductions in the total amount of available date due to the reasons enumerated above. The column labeled

"Earth viewing" refers to only non-contaminated (e.g., by charged particles) data during which the earth filled the entire field of view. Partial Earth occultation comes under the category of "Earth blocking". This last type of data cannot be used for either the sky or the cosmic-ray background measurement since both sky and earth are observed at the same time.

Since the scans were perpendicular to the galactic plane, we divided the data into intervals of 5° in galactic latitude b for the broadband data, and 10° in b for the pulse height data. No galactic plane ($|b| < 20^{\circ}$) data were used in the fluctuation measurement. Selecting alternate intervals on the sky to avoid overlap of the data with the wide collimator, we then had a batch of random samples, as well as an alternate batch. Since the spin axis of the satellite changed only a few degrees on the three days of observation, there were many instances where a choice had to be made as to which sample looking at the same piece of the sky would go into the random sample batch. The choice consistently made was for the sample with the largest exposure time. It is necessary only to work with one batch in determining the fluctuations, but we used both as a check on our estimation of the error. Both sample batches gave the same result for the relative fluctuations; all results are described later in this paper.

III. CONTAMINATION OF THE DATA

a) Geophysical Effects: The Problem of Electrons

Contamination of the data by charged particles may severely distort measurement of background fluctuations at the few percent level. Seward et al. (1973) have examined the data from numerous rocket flights with X-ray detectors aboard and found that the flux of electrons depends on solar activity and viewing direction. The geomagnetic activity indices for January 2-5, 1971 indicate average activity. The Kp index (see Solar Geophysical Data, May 1971) was about 4 on a scale from 0 to 9. No sudden commencement occurred on or during the week previous to these days. Such an event signals the beginning of a magnetic storm during which the disturbed magnetosphere can cause fluctuations in the particle background. The average daily planetary magnetic field index Ap showed January 2, 4, and 5 relatively quiet with January 3 disturbed. This was reflected in the percentage of data which satisfied the charged particle contamination criterion. For the night of January 2-3, 11% of the data could be rejected on this account, on January 3-4, 18%, and on January 4-5, 14%. While this suggests a possible correlation between magnetic field activity and detector counting rate, more data is required to determine the noise about the mean value.

At a height of $\sim$ 540 km we expect to encounter a population of quasi-trapped particles spiraling around the Earth's magnetic field lines. The 2.5-mil beryllium window of the counter corresponds to the most probable range of a 55-keV electron, but due to straggling electrons

with energies as great as 100 keV may appear as X-ray counts in the broadband detector (Schwartz 1974). Electrons of this energy at the altitude in question will bounce many times between mirror points on a time scale of << 1 second while also slowly drifting to the east. Eventually they will scatter in the atmosphere and be lost.

The magnetic shell in which an electron drifts is characterized by the McIlwain parameter L, a length which reduces to the equatorial radius of a field line in a dipole field (McIlwain 1961). For the *Uhuru* data analyzed here L varies between $\sim$ 1.05 and 1.24 Earth radii, a region populated by inner-zone electrons. The value of the magnetic field at the electron's mirror points, B, varies between $\sim$ 0.22 and 0.33 gauss. B and L would completely determine the particle's motion were it not for the violations of these adiabatic invariants due to particle collisions, wave-particle interactions, and sudden changes in the magnetic field.

In Figure 1 data taken from above the upper level discriminator (hereafter referred to as the ULD data) are plotted versus Earth longitude. Each division corresponds to 1° in longitude, or about 16 seconds. The figure shows the essential features of the electron distribution: the high, narrow spikes of "perpendicular" electrons whose pitch angle (the angle between the particle's velocity vector and the magnetic field) is 90°, and the more broadly distributed "parallel" electrons. The former mirror near the spacecraft, while the latter come down the field lines into the atmosphere below the satellite. The huge flux of electrons between about -40° and 0° Earth longitude always occurs when *Uhuru*, with

its nearly equatorial orbit, is over the South Atlantic*.

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*The dipole axis of the Earth's magnetic field is displaced about 400 km from the Earth's center. The perigee of the inner zone particle drift shells is located over the South Atlantic, so that the magnetic field intensity is much smaller there. In addition there is a true magnetic anomaly due to higher multipoles of the core field just to the west of this region (0-30°) (Schultz and Lanzerotti 1974).

The broadband data during this passage doubles in intensity.

Another feature of Figure 1 is the buildup from a parallel electron distribution to a higher perpendicular-plus-parallel flux going east of Greenwich. This results from pitch angle diffusion produced by atmospheric scattering and wave-particle interactions as the electrons drift from west to east. A discussion of the azimuthal variations in flux is given in Schultz and Lanzerotti (1974). The net effect is that electrons with critical pitch angles (close to 90°) are lost in the "anomaly" region because the L shells dip deeply into the atmosphere. Just east of the South Atlantic "anomaly" the pitch angle distribution vanishes at 90°. Gradually the intensity of electrons increases with longitude as diffusion replenishes the missing interval.

The question, of course, is whether a correlation exists between B and L and the data below the upper-level discriminator cutoff. This assumes that electrons could induce X-ray events by scattering from the collimator into the detector.

We examined the ULD data directly to determine whether or not a correlation existed between charged particles and the observed sky data. Compelling evidence for charged particle contamination comes from comparison of plots of Earth-viewing counts and ULD counts versus time or angle where an increase in the former apparently correlates with an increase in the latter. An example is shown in Figure 2. Average values for the count rates for two sequential time intervals occurring during one Earth viewing passage are tabulated above the figure to emphasize the correlation. This is only one of many obvious suggestions of contamination.

To precisely determine the degree of contamination for all of the data we computed the sums of the cross products of the deviations from the means of the two populations (Earth data and ULD data), and from this the correlation coefficient, r. For greater than 2000 samples of 0.768 seconds each for each of the three tapes, we found r to be 0.177 ± 0.014, showing an extremely high positive correlation for the number of observations. The slope of the regression line between X-ray and ULD events and its standard error, $\eta = 0.017 \pm 0.002$, follow from the above.

Assuming the same correlation between ULD and sky data (we used the Earth data as the original comparison population sample since it is free of the source confusion and possible excess fluctuations suffered by the sky data), we set a level of acceptance of X-ray contamination at 2%. Then the highest acceptable ULD rate is given by ρ in

$$\eta\,(\rho - \bar{\rho}) = .02\,\bar{X} \quad .$$

The parameter $\bar{\rho}$ is the average ULD (i.e., cosmic ray) rate, estimated by several methods to be $\sim$ 98 counts sec^{-1}; $\bar{X}$ is the mean sky rate of $\sim$ 20 counts sec^{-1}; and η is the regression line slope given above. We find ρ equals $\sim$ 122 counts sec^{-1} for the three days of data considered. Samples which had corresponding rates greater than ρ in the ULD data were rejected as contaminated. That our efforts were not exaggerated is later demonstrated (see Table 2) when we compare the spectra of the "clean" sky data and charged particle contaminated data.

b) X-Rays Scattered by the Atmosphere: A Twilight Effect

Scattered X-rays (energy $\lesssim$ 3 keV) from the sun are observed on the detector for a short while after (before) the optical sunset (sunrise), as determined by the sun sensor. To remove this source of contamination, we rejected data within a few minutes of the rising or setting of the sun when the low energy (< 3 keV) flux exceeded 3σ above nominal.

c) Contamination by Known Discrete Sources

To eliminate possible contamination from known sources to 2% of the average background rate of 20 counts s^{-1}, we rejected data for which the magnitude of source intensity (as given in the 3U Catalog) times the collimator transmission function (canonical triangular response function for a slat collimator) was greater than $\sim$ 0.4 counts s^{-1}. Only 3U sources with magnitudes greater than 5 x 10^{-11} ergs (cm^2- s)$^{-1}$ were considered as this is the limit of the *Uhuru* sensitivity (Matilsky et al. 1973). Thus, any discrete source with lower flux will contribute

to the fluctuations; this includes identified sources in the 3U Catalog as well as those not discovered by *Uhuru* because of inadequate sky coverage at this low level of sensitivity.

d) Other Contributions to the Fluctuations

It is easy to see when the Earth is in full view of the detector because the counting rate is down by a factor of ~ 6. What is more difficult to discern is when the Earth occludes only a fraction of the field of view. The amount of time it takes the detector to go from sky viewing to Earth viewing (or in the reverse sense) changes depending on the orientation of the spin axis of the satellite with respect to the Earth's horizon. Misjudging the "dipping time" will certainly increase the fluctuations and result in a systematic observance of "holes" in the background. Each spin cycle of the data was examined for this effect and a separate rejection criterion was established to eliminate data so affected.

The rejection of discrete sources has been described, but some of the difficulties with this procedure should be emphasized. First, for nonvariable sources, the source intensity used in estimating its possible contribution to the emission was the weighted average given in the 3U Catalog (Giacconi et al. 1974). Many other sources have sizable ranges over which their flux varies; neither this nor the uncertainties in the intensities was taken into account in this analysis. Secondly, errors in the positions of the sources were ignored. These errors are correlated with the errors in the source intensities. The conversion of the value of the

intensity in Uhuru counts to energy flux is subject to a 30% uncertainty due to spectral shape variations and an additional 10% due to uncertainty in the effective area of the detector (Giacconi et al. 1974).

More contributions to the fluctuations may arise from "lines of position" in the data which did not satisfy the AS&E source criteria because they were not crossed over again from a different spin axis orientation, or fell in intensity below detector sensitivity before later scans. Such "sources" were left in the data.

In the sample discussed here only one source of emission not listed in the 3U Catalog was rejected. This decision was forced by the 3-5 sigma signal of the source in different superposition periods and its occurrence in many spin cycles during two different orientations of the spin axis. All evidence points to an X-ray source of magnitude greater than 3 Uhuru counts. We would locate the source (with considerable uncertainty in longitude because of the perpendicular-to-the-plane orientation of both scan paths) at $b \sim 75^{\circ}$ and $\ell \sim 268^{\circ}$. The known X-ray source Virgo X1 at $\ell = 283.5$ is too far away to contribute such a large flux at the center of the collimator where $\ell = 267^{\circ}$. This "source" also satisfied the line of position criterion for one day.

IV. RESULTS

a) Fluctuations

Taking a random sample of 29 patches of sky approximately $5^{\circ} \times 5^{\circ}$ in galactic coordinates, we derived a weighted mean value for the sky

data (with no Earth background subtracted) of 19.90 counts s^{-1}. For 26 samples of Earth-viewing data (i.e., the cosmic ray background) we found the rate to be 3.36 counts s^{-1}. This gave an intensity, I, for the sky of 16.54 counts s^{-1}. The standard derivation of the sky samples was 0.54 counts s^{-1} while the statistical error was 0.41 counts s^{-1}. The Earth showed very little deviation in excess of Poisson statistics with a standard deviation of 0.23 counts s^{-1} and a statistical error of 0.21 counts s^{-1}. The excess sky fluctuation, δI, then becomes the square root of the difference between the standard deviation and the statistical error of the sky samples, the Earth contributing a negligible amount to the fluctuation. Including the Earth excess, we find a relative fluctuation, $\delta I/I$, for the X-ray sky background of 0.020.

To evaluate the error on this measurement we employed the Neyman-Pearson lemma which defines the critical region for the most powerful test between two alternative hypotheses (Lindgren 1968). The hypotheses being tested are that $\delta I^2 = 0$ versus δI^2 = some nonzero σ^2_{excess}. Such a test was applied to the case of the microwave background by Boynton and Partridge (1973). We have modified the form of the critical region described by them to include the cosmic ray background error (i.e., standard deviation of the Earth viewing data). The statistic appropriate in this case to the most powerful test becomes

$$\mathcal{S} = \sum_m \frac{Um^2}{\sigma_m^2\,(\sigma_m^2 + \sigma^2_{excess} + \sigma^2_{earth})} > \gamma$$

where $[U_m]$ are the deviations of the samples (m) from the mean; $[\sigma_m]$ are the statistical errors on the samples (m); and γ prescribes the critical region which may be used to define the confidence level. By redefining the number of degrees of freedom (as described in the above referenced article by Boynton and Partridge), the statistic may be made a χ^2 variable. The *Uhuru* data analyzed here then says that the hypothesis that $\delta I/I \geq 0.029$ may be rejected at the 90% confidence level. The fluctuations are over a solid angle of 0.0042 sterad (Schwartz et al. 1975). It should be noted that the alternate batch of samples also gave $\delta I/I = 0.020$, with an upper (90% confidence) limit of 0.025.

b) The Source Counts

It is possible from the observations alone to estimate the number of X-ray sources near the intensity corresponding to one source per beam width (Scheuer 1974). We wish to find the best-fit parameters in the equation for the differential source counts:

$$N(S)\ dS = KS^{-\beta}\ dS\ ,$$

where N(S) dS is the number of sources per steradian of true intensity S to S + dS. If we postulate a Euclidean universe where the sources are distributed uniformly up to some finite distance, $\beta = 2.5$. The choice of this model is consistent with the results of Matilsky et al. (1973), Holt et al. (1974), and Fabian (1975).

The probability distribution of fluctuations for variable values of K and β has been worked out for the case of the triangular beam of the

egg-crate collimators used in X-ray sky observations by Scheuer (1974), using the method of characteristic functions. For $\beta = 2.5$, we convolved this probability distribution (cf. eq. 12 of the Scheuer 1974 reference) with the Gaussian distribution due to photon noise and the excess Earth (cosmic ray) fluctuation.

Fitting the observations to the convolution, we find a χ^2 minimum for K = 8. The total χ^2 minimum was 4.17 for 6 degrees of freedom. An error on K may be calculated using the prescription of Lampton _et al_. (1975). At the 90% confidence level we find:

$$N(S)\ dS = 8 \begin{pmatrix}+15\\-\ 8\end{pmatrix} S^{-2.5}\ dS\ .$$

Figure 3 shows the predicted distribution of fluctuations and the convolution for K = 8. The observed distribution of the data is also illustrated.

Again we must point out that the power-law index reflects an _assumed_ cosmological model. We may compare this to the Log N vs. Log S curve for 2U Catalog sources which suggests $K \simeq 64$ (Matilsky _et al_. 1973), to that curve for the 3U Catalog sources where $K \simeq 60$ is found (Holt _et al_. 1974), and to the value K = 25 (±10) derived by Fabian (1975). Integrating the above expression for N(S), we find that no more than 156 sources should be observed between 1 and 3 _Uhuru_ counts ($1.7 - 5.1 \times 10^{-11}$ ergs cm^{-2} s^{-1}), in contrast to the 433 predicted by the Matilsky _et al_. curve.

c) Energy Distribution

In Table 2 we list for each of the seven pulse height channels the energy range, mean counting rate and photon statistical error for clean sky data and for data designated as contaminated because of high counting rates in the upper-level discriminator channel. In the last column the difference between the two rates is divided by the clean sky rate; thus, it is a measure of the contribution of a high particle background to the spectral intensity.

To determine the intensity coefficient and spectral index of the power law ($AE^{-\alpha}$) which best fits the data we used the efficiencies for the detector as calculated by Schwartz (private communication) and the corrections to the pulse height channels. These corrections were determined (Schreier, private communication) by comparing the observed counts per channel per second from the Crab with those predicted by the power law:

$$I\ (E) \simeq 9\ E^{-0.99}\ \mathrm{keV(cm^2\text{-}s\text{-}keV\text{-}sterad)^{-1}}\ .$$

A χ^2 test gave a minimum value for the spectral index of $\alpha = 1.41$. The probability of exceeding this minimum value of χ^2 was 0.10. Included in the errors for each channel were the errors due to photon statistics and the errors due to the uncertainties in the Crab spectral slope and cutoff. An error of 0.04 on α was determined using the 90% confidence interval of Lampton et al. (1975). Including a determination of the intensity, we find: $dN/dE \simeq 7\ E^{-1.41\pm0.04}$ photons$\mathrm{(cm^2\text{-}s\text{-}keV\text{-}sterad)^{-1}}$ for the diffuse sky background.

V. OBSERVATIONS OF THE GALACTIC PLANE

An attempt was made to test a correlation of the counting rate of the low energy (1.8-2.4 keV) channel for $|b| < 20^{\circ}$ with the column density of interstellar atomic hydrogen. If at least a large fraction of the X-ray background is indeed extragalactic, we would expect to see a reduced flux at low energies due to H I absorption along the line of sight. This effort was obviated by the large statistical errors in the rates, even when the data was summed over 10° in b. The lack of good statistical data was a result of deleting possible contributions from the numerous discrete sources in the plane, rejecting data because of solar contamination and Earth blocking, and the inherently low counting rate of the channel being analyzed. The few instances where an absorption effect might be seen are only of one sigma significance.

The broadband data were potentially more statistically significant for the test of emission theories. We measured a few percent (4.5% for $E > 3.4$ keV) overall increase in the plane flux over the background at higher latitudes. It is likely (see the review by Silk 1973, Section 5b) that this "ridge" is due to weak, unresolved sources. From the limited range in longitude of our sample, we cannot discuss variations in the intensity of the ridge with direction (i.e., associations with the spiral arms), or infer the gradient towards the galactic center. The spectrum of the excess plane emission has the same shape as that for $|b| > 20^{\circ}$ for energies higher than 3.4 keV. Below this, the spectrum has a steeper cut-off, suggesting H I absorption of the extragalactic component of the diffuse emission.

VI. DISCUSSION

There is no unanimous agreement on the source of the diffuse X-ray emission. Any model must be consistent with the observed isotropy and intensity of the radiation. Silk (1973) has reviewed the arguments for the inverse Compton mechanism, thermal bremsstrahlung from a diffuse hot intergalactic gas, and the contribution of discrete extragalactic sources, including the existence of a hot, ionized intracluster gas as a diffuse X-ray source.

Considering the discrete source model, it is of interest to find what number of weak, unresolved sources is required to account for the observed fluctuations. This has been done for the microwave background (Smith and Partridge 1970) where evolutionary cosmological models and Thomson scattering by intergalactic matter have been taken into account. It is clear that smaller relative fluctuations imply a larger number of sources if we assume (following the discourse by Smith and Partridge) that first, the sources are of the same apparent luminosity and are distributed uniformly throughout the universe; second, the sources are statistically independent; third, the sources are formed before some early epoch; and last, the sources are not visible for z less than some small z_o. As Smith and Partridge point out, all assumptions but the third are conservative in the sense that a change in any of them only increases the fluctuations. Hence the number of sources required will not be overestimated. Smith and Partridge parameterize the relation between density and relative fluctuations by the quantity

$$\mu = n\,\Omega\left(\frac{\delta I}{I}\right)^2 . \tag{1}$$

They find a minimum value for μ of $\sim 2.5\ 10^{-13}$ ster/Mpc^3 for $q_o > 0.02$. This figure does not include any assumptions other than the above, hence it is a number relevant to the X-ray case if it is postulated that the background is comprised of discrete sources alone. Using the upper limit to $\frac{\delta I}{I}$ of 2.9% and the effective solid angle of 0.0042 steradians, the number density of sources required is $n \geq 10^{-7}$ Mpc^{-3}.

An alternative is that discrete sources form only part of the total X-ray sky background with various types of sources (normal galaxies, clusters of galaxies, Seyferts, supernova remnants and quasars, for example) contributing different amounts. The dependence of the fluctuations on the effective beam area, the number density of sources, the spatial extension of the sources, and the fraction of the X-ray background due to the sources, ρ_b, is derived by Rowan-Robinson and Fabian (1974). The relationship shows:

1) the fluctuations are proportional to $n^{-1/3}$;
2) the fluctuations decrease as the sources become more extended;
3) as the effective beamwidth increases, the fluctuations decrease;
4) the fluctuations are linear in ρ_b; and
5) the fluctuations are inversely proportional to χ, a cosmological parameter equal to 1/2 in the Milne cosmology.

Their calculation gives $n \simeq 10^{-4}\ (\rho_b)^3\ (\frac{0.5}{\chi})^3$ Mpc^{-3} where our value for the background intensity has been used. This discussion is especially appropriate to the X-ray background since the 3U Catalog of sources

detected by *Uhuru* between 2 and 10 keV contains 62 high latitude sources, of which about 2/3 are unidentified. If the source counts are corrected for uniform sky coverage and a lower limit $S_o = 5 \times 10^{-11}$ ergs(cm^2-s)$^{-1}$ (or 3 *Uhuru* counts) is used because of the uncertainty in the sky exposure correction for weaker sources, a value of 97 equivalent sources of intensity greater than S_o over the entire sky is derived from the Log N vs. Log S curve. Using this and the effective solid angle of 0.0042 sterad, a relative fluctuation of 5 % is predicted (Schwartz et al. 1975). This may be compared with the 2.0% relative fluctuation measured using the random sample previously described. There are at least two ways of viewing this inconsistency. One is to say that the unidentified high-latitude Uhuru sources do not form a homogeneous population at non-cosmological distances (Holt et al. 1974, Schwartz et al. 1975); the second is to assume an error was made in estimating the source counts. Fabian (1975) suggests that the slope of the source counts may cause weak sources to be detected at intensities greater than their true intensities, and that some of the weak high latitude source counts may be due to source confusion.

VII. CONCLUSIONS

The present measurement of a 2.0% spatial fluctuation over an angular scale of 0.0042 sterad rules out the possibility that normal galaxies lying in superclusters contribute more than 30% of the background flux (Rowan-Robinson and Fabian 1974). However, normal galaxies with no evolution predict the correct fluctuations if they supply the entire background radiation. However, the number density of normal galaxies is 3 orders of magnitude larger than the number density of X-ray sources. As emphasized by Rowan-Robinson and Fabian (1974), the question of which single population of sources could, with or without evolution, contribute most of the background radiation can only be decided when constraints on the evolution of the sources can be made on the basis of further identifications of the high-latitude population, and the angular scale of the fluctuations can be determined.

We believe that the limit on the fluctuations derived in this analysis is lower than previous measurements because of the care taken to remove sources of contamination which were either not identified or ignored as insignificant by other investigators. These sources were found to produce small, but systematic increases in the background rate with respect to time, angle, energy, or spatial coordinates. Our attempt to remove contaminated data to a level of 2% of the nominal background flux is consistent with the upper limit of 2.9% fluctuations measured. The fact that we find such a large discrepancy between the predicted (5%) and the observed (2%) fluctuations suggests that the source counts are in error and/or that the basic assumption of homogeneously distributed point sources (β = 2.5) is incorrect.

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Table 1

IDENTIFICATION OF TYPES AND AMOUNTS OF CONTAMINATED DATA FOR JAN 2-5, 1971

Total Amount of Nighttime data (seconds)	% Contaminated and its Cause						% Good Sky Data Remaining**
	Instrumental*	S. Atlantic Crossing	Electrons	Partial Earth Blocking; also, Sun	Total Earth Viewing	Discrete Sources	
62,949	6	25	$14\frac{1}{2}$	7	16	$6\frac{1}{2}$	25

* Instrumental Contamination includes parity errors, lack of aspect information due to telemetry dropouts or lack of star sensor data, pulse shape discriminator disabled, instrument noise bursts, etc.

** includes $|b| < 20^{\circ}$.

Table 2

ENERGY SPECTRA FOR THE SKY DATA*

SHOWING CONTAMINATION BY ELECTRONS

Energy Interval (keV)	With Low Electron Bkgrnd. (counts sec^{-1})	With High Electron Bkgrnd. (counts sec^{-1})	% Excess Due to Electrons
1.8 - 2.4	2.38 ± 0.01	2.47 ± 0.03	3.8
2.4 - 3.4	5.82 ± 0.02	5.99 ± 0.04	2.9
3.4 - 4.5	5.33 ± 0.02	5.58 ± 0.04	4.5
4.5 - 5.7	5.66 ± 0.02	5.88 ± 0.04	3.9
5.7 - 7.1	5.19 ± 0.02	5.31 ± 0.04	2.3
7.1 - 8.6	3.37 ± 0.02	3.49 ± 0.03	3.6
8.6 - 10.0	1.76 ± 0.01	1.84 ± 0.02	4.5

*Cosmic Ray Background (Earth-viewing data) not subtracted

Errors are only those due to photon statistics.

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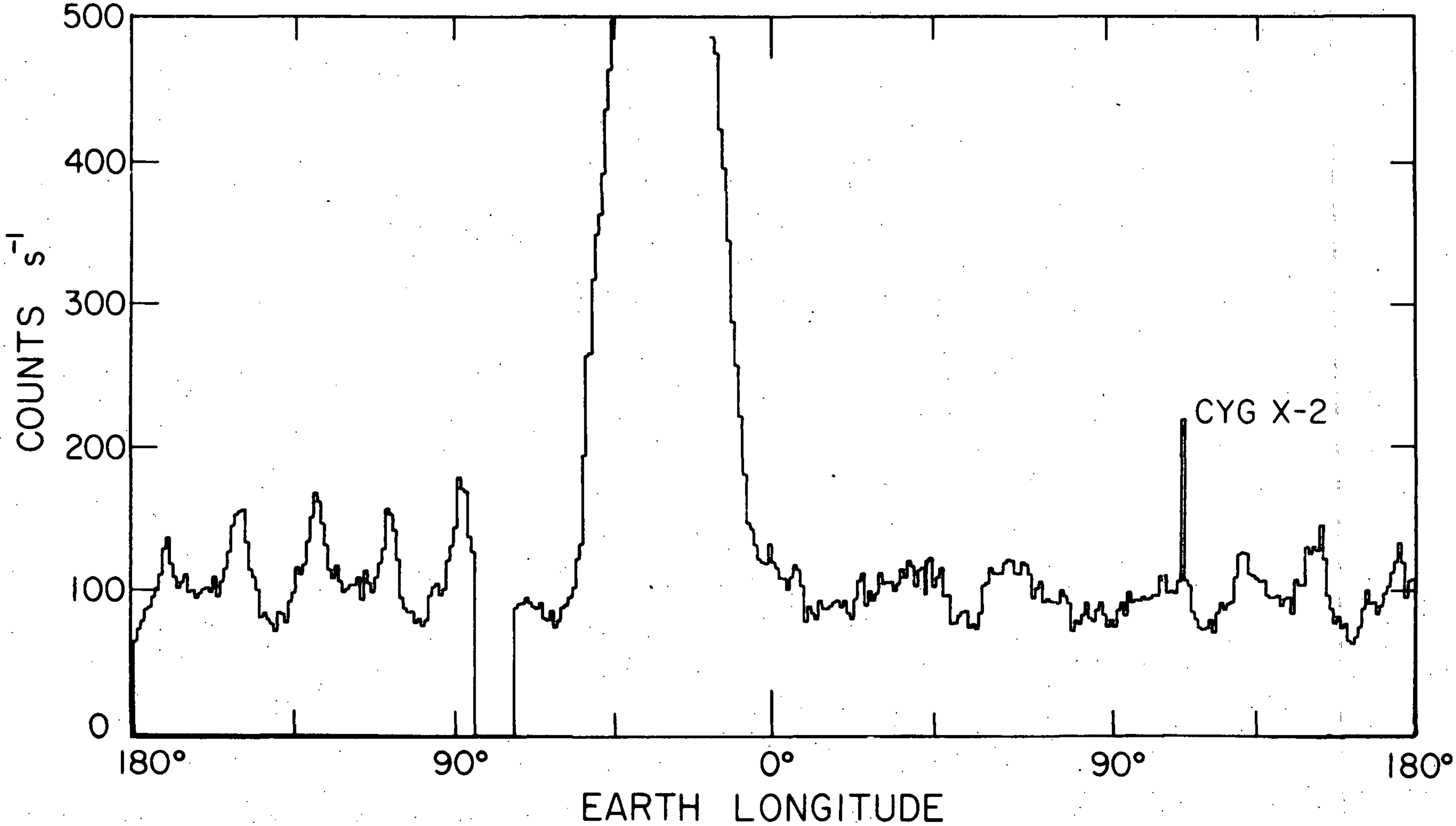
FIGURE CAPTIONS

Fig. 1 - The counting rate of the data from above the upper level discriminator (ULD) is plotted vs. Earth Longitude in 1^{o} bins. The South Atlantic region (about -40^{o} to 0^{o}) contributes the largest flux of electrons.

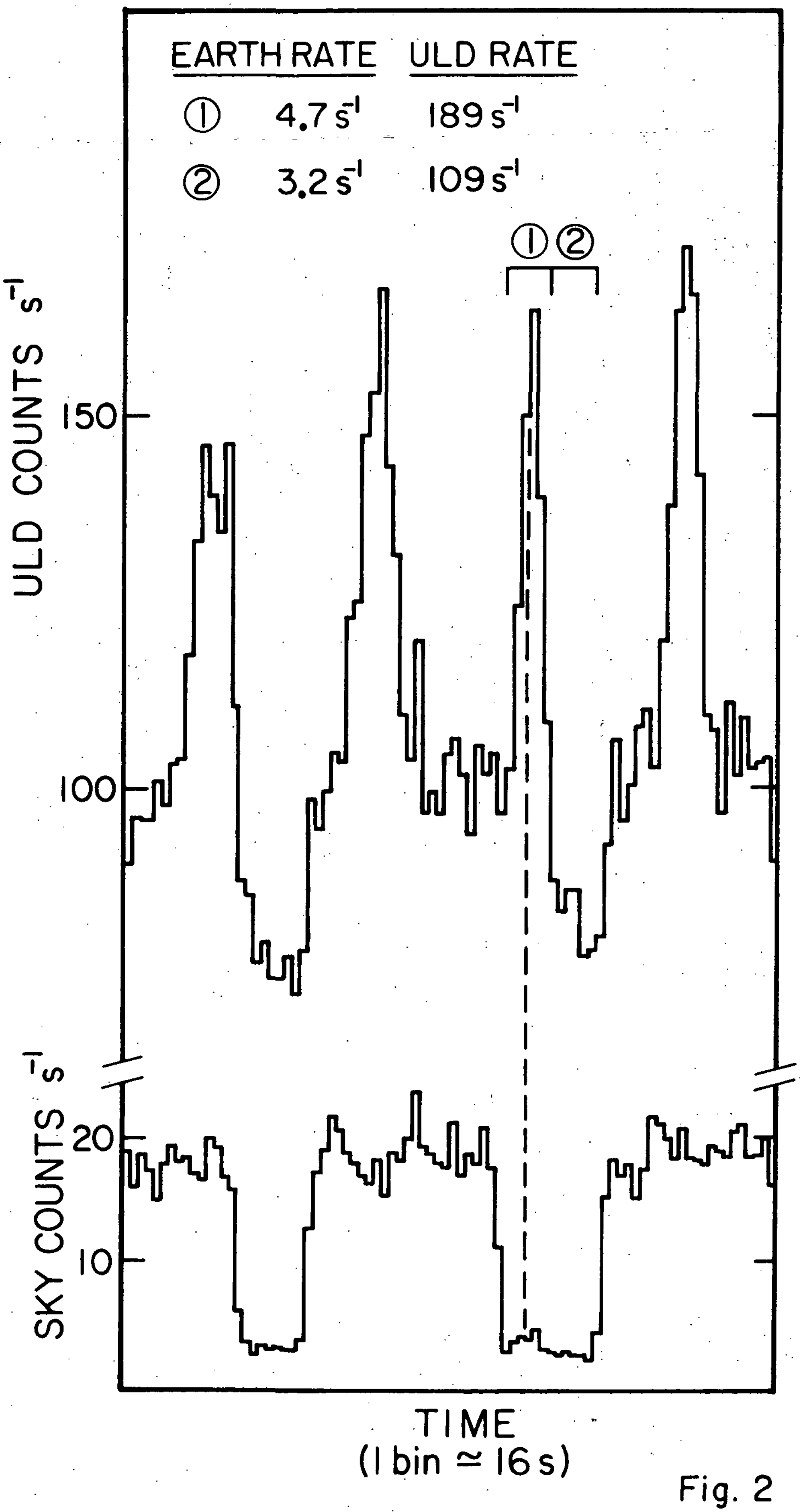
Fig. 2 - Evidence of charged particle contamination can be seen in this comparison of the ULD data and 2-7 keV data vs. time. The average ULD and Earth viewing rates are compared for two adjacent sections of data, labeled 1 and 2.

Fig. 3 - The distribution of the observations (histogram) is compared with the probability distribution of fluctuations (dashed curve) and its Gaussian convolution with the noise (open circles) for the χ^2 best fit value of K.



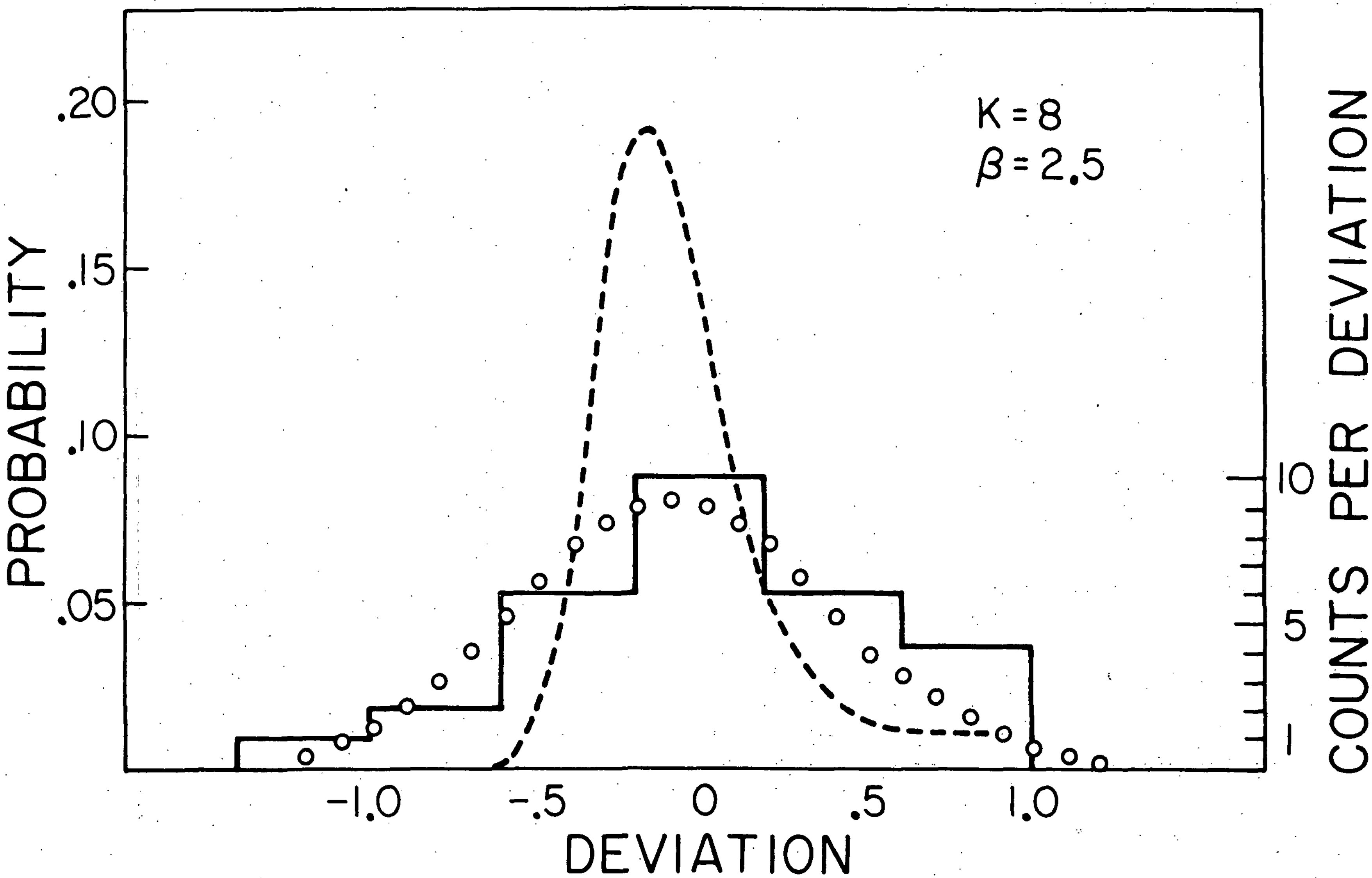
500
400
300
200
100
0
COUNTS s^{-1}
CYG X-2
180°
90°
0°
90°
180°
EARTH LONGITUDE

Fig. 1



EARTH RATE ULD RATE
① 4.7 s⁻¹ 189 s⁻¹
② 3.2 s⁻¹ 109 s⁻¹
① ②
ULD COUNTS s⁻¹
150
100
SKY COUNTS s⁻¹
20
10
TIME
(1 bin ≃ 16 s)

Fig. 2



K = 8
β = 2.5
PROBABILITY
.20
.15
.10
.05
COUNTS PER DEVIATION
10
5
1
-1.0
-.5
0
.5
1.0
DEVIATION

Fig. 3